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Intelligent Patient Flow Management System at a Primary Healthcare Center – The Effect on Service Use and Costs

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Abstract. An intelligent patient flow management system (IPFM) was piloted at a large primary healthcare center in Finland in August 2017. The goals of the system are to help patients avoid unnecessary calls and visits to their health center and to enhance the use of professional resources through more streamlined patient pathways and the re-allocation of professionals from assessment tasks to actual patient care. These goals should be reflected in the decreased service costs through optimized contact forms. Using multiple regression analysis, we studied the associations between IPFM and patients' service utilization (17,943 patients; 73,038 service contacts) during the first five months of the pilot in 2017. The results indicated that the use of IPFM by the patient was associated with a decrease of EUR 31 in the total service costs of the patient in the study period. This decrease is 14% of patient's average total service cost.

Keywords. Intelligent patient flow management, artificial intelligence, primary health care, service utilization, health system performance

1. Introduction

An intelligent patient flow management system (IPFM) was introduced as a 10-month pilot in August 2017 at a large public primary healthcare center of Myyrmäki region in the city of Vantaa, Finland. Developed by a private healthcare technology company, Klinik Healthcare Solutions Oy, this system is a web-based service that aims at streamlining the patient flow by combining preliminary health issue information and symptom checking with intelligent medical diagnostics engine that utilizes artificial intelligence and machine learning algorithms.

Patients use the system by reporting their symptoms and issues online in a structured format and submitting the report to the healthcare center through the system. By immediately analyzing the information provided, the system detects the most probable diagnoses and the urgency of the case and directs the patient timely to the most appropriate point of care. All information is transferred in real time to the designated healthcare professionals' IPFM-dashboard. Based on the prehistory provided by the

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patient and the IPFM provided medical information (treatment options, diagnoses, urgency), the professionals initiate the care pathway. The goal of IPFM is to help patients avoid unnecessary calls and visits to their health center and to make treatment planning and patient flow management more efficient for the healthcare centers. The IPFM is expected to enable more streamlined patient pathways with fewer delays for the patients. In addition, a decrease in unnecessary service contacts releases professional resources from assessment tasks to actual patient care.

In this study, we investigated the connections between IPFM and patients' service utilization during five months in 2017, from 7th of August to 31st of December. We posed the following research questions: RQ1: Is there a statistically significant association between patient using the IPFM at least once and patient's service costs during the study period? RQ2: Is this association positive or negative and how large is it?

2. Data and Methods

2.1. Data

The data consist of registry data about patients' service use at Myyrmäki health center from 7th of August until 31st of December 2017, including nearly five months of service records. In the records, the services related to patient care are divided into seven categories: Physical appointment, Phone call, IPFM-derived contact, Consultation, Letter, Documentation without customer contact, Other. The costs of the services were calculated by combining the service category and the healthcare professional group (General physician, registered nurse, practical nurse etc.), and by following the index-adjusted costs reported in a national guideline from 2011 [1]. As there were only few hundreds of patients' diagnoses coded using ICD-10 and several thousands of diagnoses coded using ICPC, all the ICPC records were converted into ICD-10 records to enable a more reliable calculation of Charlson index of comorbidity (CCI) [2].

2.2. Methods and Model Specification

OLS multiple regression analysis was used to explore the associations and answer the research questions. The dependent variable was patient's total service costs (*TSC*) during the 5-month study period at the healthcare center. The explanatory variable was the binary IPFM use, i.e. whether the patient had used the system at least once during the pilot period in 2017.

In order to control for the factors that could explain differences in service costs of the patients, we used several control variables including demographic characteristics such as patient age and gender. Charlson index of comorbidity (CCI) was added to control for the variation in patients' comorbidity [2]. Since contacts regarding a new health issue tend to be longer and more complicated, we added the information about patients' first contacts (FC) in the regression. The same logic applies for conducting general triage (TRI), which was also controlled for.

Whether the patient had any contacts on Mondays (M) was added to the model to account for the fact that overcrowding tends to be worst on Mondays, because of, inter alia, inadequate numbers of patients discharged over the weekend, and more urgent attendances [3,4,5]. Therefore, patients with contacts on Mondays may have prolonged or more complex service encounters, increasing costs.

We fitted the following OLS regression model [Eq. (1)] to explain patient's total service costs:

$$TSC = \beta_0 + \beta_1 IPFM + \beta_2 age + \beta_3 gender + \beta_4 FC + \beta_5 TRI + \beta_6 M + \beta_7 CCI + u \quad (1)$$

Statistical analysis was performed using STATA 15. A p-value of less than 0.05 was used to establish statistical significance.

3. Results

3.1. Sample Characteristics

Table 1 presents the sample characteristics and the differences in key variables between groups using and not using the IPFM. Approximately 4% of patients (n=677) had used the IPFM at least once in the study period. The average number of total service contacts of a patient was four, and the highest number of contacts was 54. Patient's average TSC were approximately EUR 221 (median: EUR 126). The costs ranged between EUR 13 and EUR 3072. The group using IPFM had slightly more contacts (p<0.001) and higher mean TSC, but the latter was not a statistically significant difference.

Around 59% of the patients were women and the average age was 50 years. For 51% of the patients, there was at least one first contact during the pilot period in 2017, and for 55% one triage at minimum was reported. On average, the IPFM group had a higher proportion of women and consisted of younger patients. They also had more patients with first contacts, contacts on Monday, and, by default, contacts with triage performed, which could be contributing to the slightly higher service contacts and costs. However, the IPFM group had a lower proportion of patients with at least one physical appointment (p<0.001). Physical appointment belongs to the most costly service contact category.

Table 1. Sample characteristics and observed differences between groups using and not using IPFM.

Variable	Total population (n= 17,943)	Min – Max	IPFM (n=677)	non-IPFM (n= 17,266)	p value (t-test / Chi-Square)
Total service costs, mean (SD)	220.60 (247.63)	12.79 – 3071.9	234.49 (226.14)	220.06 (248.42)	0.137
Total no of contacts, mean (SD)	4.07 (4.44)	1 – 54	4.9 (4.07)	4.04 (4.45)	0.000*
Female, n (%)	10,578 (58.95)		466 (68.83)	10,112 (58.57)	0.000*
Age, mean (SD)	49.75 (24.89)	0 – 99	40.79 (19.10)	50.1 (25.03)	0.000*
Triage, n (%)	9,918 (55.28)		676 (99.85)	9,242 (53.53)	0.000*
First contact, n (%)	9,042 (50.75)		442 (65.29)	8,600 (50.17)	0.000*
Monday, n (%)	8,206 (45.73)		375 (55.39)	7,831 (45.36)	0.000*
CCI, mean (SD)	0.04 (0.25)	0 – 8	0.03 (0.19)	0.05 (0.26)	0.055
Physical appointments, n (%)	14,216 (79.23)		494 (72.97)	13,722 (79.47)	0.000*

*p<0.001

Less than 4% of the observed patients had one or several severe medical conditions included in the Charlson comorbidity index (Table 2).

Table 2. Charlson index of comorbidity (CCI) for the sample.

CCI	Freq.	Percent	Cum.
0	17,306	96.42	96.42
1	490	2.73	99.15
2	145	0.81	99.96
3	6	0.03	99.99
8	1	0.01	100
Total	17,948	100	

3.2. Regression Results – IPFM and Service Costs

The association between IPFM and patient's TSC is negative and statistically significant (p<0.001) (Table 3). Patient's use of IPFM is associated with a decrease of approximately EUR 31 in the TSC. This is 14% of patient's average total service costs.

As speculated, the following control variables had a positive and statistically significant association (p<0.01) with the TSC: age, triage, first contact, Monday and CCI. One additional year of age was associated with EUR 2.8 increase in TSC. If triage had been performed to the patient during any of the contacts, this was connected to EUR 98 cost increase. The cost increase related to having one first contact or more during the study period was EUR 77 and having at least one contact on Monday was EUR 160. Having medical conditions included in the CCI increased TSC on average by EUR 126 during the study period. IPFM and the control variables can explain approximately 36% of the variance in the total service costs. The distribution of residuals was close to normal and not very skewed in the kernel density estimate, increasing model acceptability.

Table 3. OLS regression results.

TSC	Coef.	SE	t	P>|t|	[95% Conf.Interv.]	
IPFM	-30.79	7.93	-3.88	0.000*	-46.33	-15.25
Age	2.81	0.06	44.08	0.000*	2.68	2.93
Female	2.74	3.03	0.90	0.367	-3.21	8.68
First contact	76.81	3.56	21.56	0.000*	69.82	83.79
Triage	97.56	3.80	25.65	0.000*	90.1	105.01
Monday	160.38	3.18	50.50	0.000*	154.16	166.61
CCI	126.04	5.94	21.23	0.000*	114.40	137.68
Constant	-90.94	4.48	-20.30	0.000*	-99.73	-82.16
*p<0.001						

4. Discussion and Conclusions

The aim of this research was to assess the service cost effect of implementing an IPFM in a primary healthcare center context. The use of IPFM was associated with approximately EUR 31 cost decrease. Considering the whole patient volume of 17,943 patients in the study period, this would mean EUR 552,000 reduction to the total average service costs (approx. MEUR 3.96). Based on the national index-adjusted cost report [1], EUR 31 cost reduction is comparable to:

- One ED nurse visit (EUR 34); three ED nurse phone calls (EUR 10); nearly three primary care nurse phone calls (EUR 12); two primary care nurse letters or electronic contacts (EUR 14).

- One ED doctor consultation (EUR 35); more than one ED doctor phone call (EUR 23); more than one primary care doctor phone call (EUR 26); one primary care doctor letter or electronic contact (EUR 34).

This research provides preliminary evidence on the cost-reduction effect of implementing an IPFM. Interestingly, this cost-reduction effect does not straightforwardly appear to follow from fewer service contacts, as the IPFM group had slightly more service contacts than the non-IPFM group, and no significant association between IPFM and number of service contacts was discovered in the other OLS regressions we ran. Due to fewer patients with physical appointments in the IPFM group, we suspect that the cost effect is based on the management of patient pathways towards less costly service contacts through better workflow. The right level and timing of care could often be the mechanisms leading to decreases in costs with same or improved health outcomes. However, as the 5-month study period was rather short and there were less than 1000 patients using the IPFM, further research is needed to assess the effect of the implementation and to analyze the shifts from certain service contact forms to another.

A severe limitation of this study is the potential selection bias, as those who ended up using IPFM may not be comparable with those who did not. We were able to control for a limited set of variables that may be associated with use of IPFM and/or cost of care. However, we could not control for e.g. socioeconomic status and health literacy that may have a substantial effect on both willingness and ability to use IPFM as well as on health care utilization. Furthermore, the proportion of patients with severe comorbidities (Charlson comorbidities) was relatively low, which indicates that the follow-up of 5 months may have been too short to detect the chronic conditions of the patients.

After considering the selection bias, these preliminary findings suggest that the use of an IPFM may reduce service costs in primary care setting.

Conflicts of Interest

Author MD Petteri Hirvonen is the COO of Klinik Healthcare Solutions Oy. Other authors did not disclose any conflicts of interest.

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References

[1] S. Kapiainen, A.Väisänen, T. Haula, *Terveyden- ja sosiaalihuollon yksikkökustannukset Suomessa vuonna 2011*, THL Raportti 3/2014, Finland, 2014.

[2] V. Stagg, *CHARLSON Stata module to calculate Charlson index of comorbidity*, Boston College; 2006. URL: http://ideas.repec.org/c/boc/bocode/s456719.html [Accessed May 2018]

[3] B.R. Asplin, T.J. Flottemesch, B.D. Gordon, Developing Models for Patient Flow and Daily Surge Capacity Research, *Academic Emergency Medicine* **13** (11) (2006), 1109-1113.

[4] J.C. Pham, R. Patel, M.G. Millin, T.D. Kirsch, A. Chanmugam, The Effects of Ambulance Diversion: A Comprehensive Review, *Academic Emergency Medicine* **13** (11) (2006), 1220-1227.

[5] D.B. Richardson, Increase in patient mortality at 10 days associated with emergency department overcrowding, *The Medical Journal of Australia* **184** (5) (2006), 213-216.